Preliminary Results of Investigations on Clay Minerals in the Vocontian Basin and its surroundings (SE France) at the Jurassic-Cretaceous Boundary

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Abstract

Investigations of the insoluble residues in the Jurassic - Cretacous boundary beds of the Vocontian Basin (SE France) and its surroundings show that their clay fraction is mainly composed of illite, smectite and kaolinite. No significant change in the clay proportions is observed during the period studied. Kaolinite is proposed, with some restrictions, as a mineralostratigraphical marker. Chlorite occurs only in the profiles situated in the nappe of Digne.

Résumé

L'étude du résidu insoluble de quelques affleurements à la limite Jurassique - Crétacé du domaine vocontien et ses bordures a montré que la fraction argileuse se compose essentiellement d'illite, de smectite et de kaolinite. Il n'y a pas de changements significatifs dans la composition de la fraction argileuse pendant l'intervalle étudié. La kaolinite est proposée, avec quelques réserves, comme marqueur minéralostratigraphique. La chlorite n'existe que dans les coupes situées dans la nappe de Digne.

Zusammenfassung

Untersuchungen des unlöslichen Rückstandes einiger Aufschlüsse der Jura-Kreide Grenzschichten des Vocontischen Troges und seiner Randgebiete ergeben, dass sich die Tonfraktion im wesentlichen aus Illit, Smektit und Kaolinit zusammensetzt. Es gibt keine bedeutenden Schwankungen in der Zusammensetzung der Tonfraktion während des Untersuchungszeitraumes. Kaolinit wird - unter gewissen Vorbehalten - für mineralstratigrafische Korrelationen vorgeschlagen. Chlorit ist nur in den Profilen aus dem Bereich der Decke von Digne nachgewiesen.

Resumen

Se estudia el resíduo insoluble de unos afloramientos del límite Jurásico - Cretácico en la Cuenca vocontiense y sus bordes. La fracción arcillosa se compone esencialmente de ilita, esmectita y caolinita. No hay cambios significativos en la composición de la fracción arcillosa en el intervalo estudiado. Se propone con algunas restricciones la caolinita como marcador de referencia mineralo-estratigráfico. La clorita existe solamente en los afloramientos del manto de corrimiento de Digne.

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1. Introduction

1.1. General Aspects and Geographical Setting

In this paper we present some results of investigations on clay minerals (fraction <2 µm) of the Jurassic - Cretaceous boundary beds. So far about 750 samples from 23 sections have been studied (tab. 1, 2 and fig. 1).

The region studied does not consist of a well-defined geographical unit: it includes parts of the Northern Subalpine Chains (Chartreuse), the Southern Subalpine Chains and its Southern borderlands (region of Castellane) as well as the Ardèche - Cevennes region. But the region forms during Jurassic - Cretaceous times a well-known paleogeographical unit: the Vocontian Basin and its surroundings, which can be defined as a triangle of sedimentary rocks between Grenoble in the North, Castellane in the South and the Département du Gard to the Southwest.

1.2. Geological Setting

In the Vocontian Basin the Upper Jurassic and partly the Berriasian are characterized by an important development of marine carbonate facies. This position has allowed, a long time ago already, the introduction of an Ammonite-based biochronological zonation (c.f. tab.3). Historically (c.f.1.3.), the Jurassic - Cretaceous boundary was defined in that particular region (KILIAN 1888, MAZENOT 1939).

In the Basin, the Upper Tithonian consists of an open marine (pelagic) facies with Calpionellids. The average thickness varies between 20 and 30 m. Electronic microscopy done by FLÜGEL (1967) showed that these limestones are formed essentially of Coccolithes and *Nannoconus* . Furthermore, there are resedimented intercalations within these monotonous series, whose importance and total sedimentation part may vary locally or regionally to a considerable extent. These resedimentations with its massive breccias of turbidite origin reinforce a morphology that is quite characteristic for the region : the so-called "barre tithonique". The resedimentations are explained by REMANE (1960, 1970) by turbidity currents to which this author attributed an important erosive power.

On the Southern border of the Jura platform, the Jurassic - Cretaceous boundary beds are characterized by a build-up of reef constructions and emersion tendancy ("regression purbeckienne": DECONINCK & STRASSER 1987). At the Bec de l'Echaillon, these massive reef-limestones have a thickness up to 250 m.

The Berriasian (some 10 m) consists of an alternance of marls and carbonate sediments as well as resedimentations. The intercalations of these resedimentations have been studied by GOGUEL (1938) and DONZE & LE HEGARAT (1966b). In these publications it has been shown that the formation of these breccias is due to submarine slumping which caused a mixing of pelagic and neritic elements.The passage from the micritic Upper Jurassic limestone facies to the more marly facies of the Lower Cretaceous can be either quite sharp, or progressive. Sometimes there is also a stratigraphical hiatus or a hard-ground at the top of the Upper Jurassic.

Micropaleontological research and especially the study of Calpionellids (REMANE 1963, 1964, LE HEGARAT & REMANE 1968, ALLEMANN et al. 1971) have allowed to establish a biochronological zonation (tab. 3).

1.3. Historical and Biochronical Setting

In this paper only a few authors shall be mentioned because an excellent overlook of the existing litterature is stressed out in the memoire 125 of the B.R.G.M. ("Synthèse géologique du Sud-Est de la France") published in 1984.

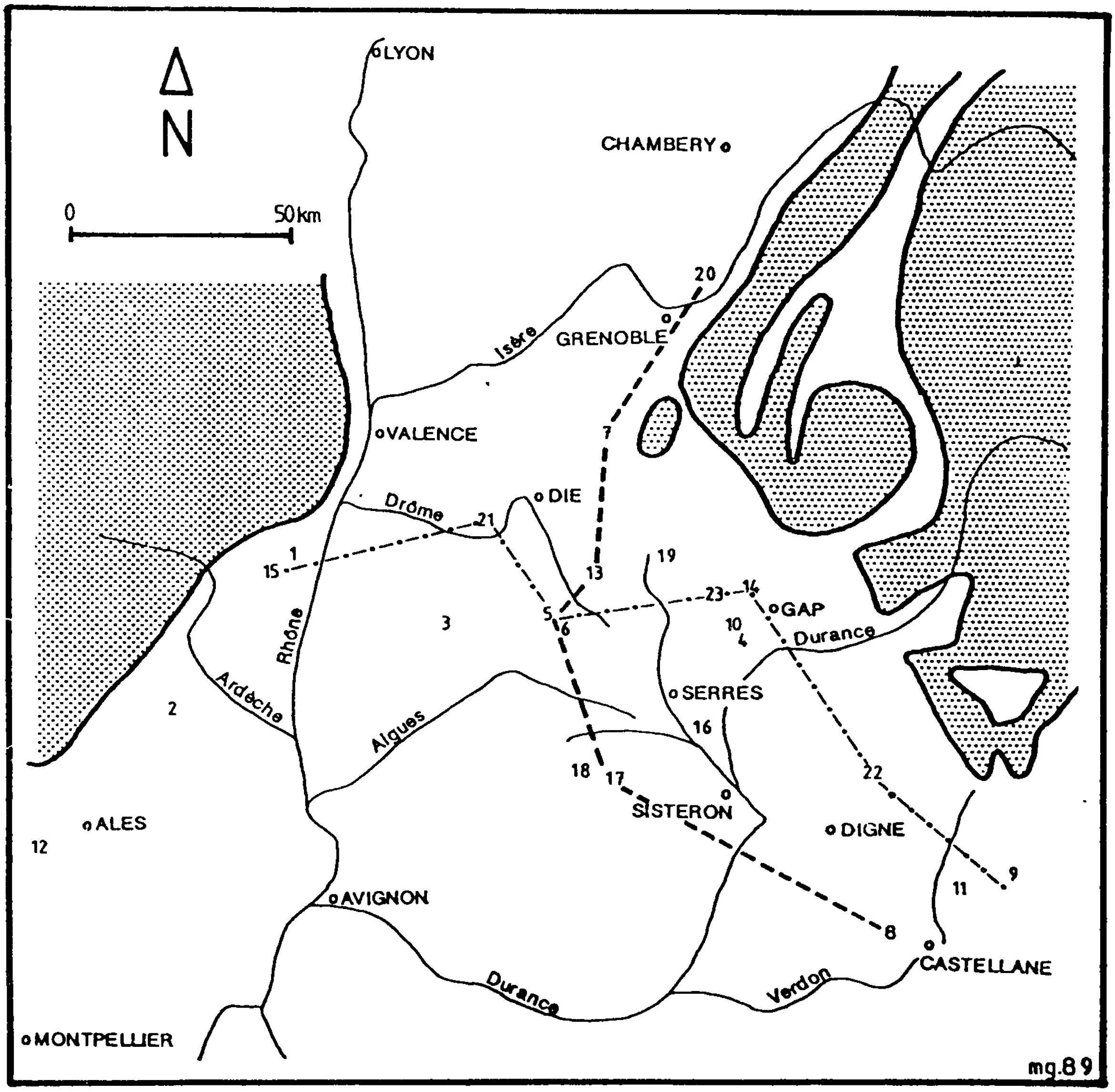

Fig.1

Location of the sampled sections and the cross-sections of fig.4 and 5

Localisation des coupes étudiées et les profiles des fig. 4 et 5

Lage des untersuchten Aufschlüsse und der Profile aus Fig.4 und 5

The Calpionellid-zonation we used in the present paper has been established by REMANE (1963, 1964). LE HEGARAT & REMANE (1968) correlated Ammonites with Calpionellid-associations in the Cevennes Borderlands, so did ENAY & GEYSSANT (1975) in the Spanish Subbetic Ranges. By these and other authors the great importance of the Vocontian Calpionellid-stratigraphy for the whole Tethyan realm was stressed out. More recently, this zonation has also turned out to be of use in North Atlantic Deep Sea Drilling projects. CECCA (1986) gives an excellent paleontological and stratigraphical overview of the Tithonian in the Ardèche region.

Mineralogical and geochemical research started in 1976 with PERSOZ & REMANE, who showed that kaolinite appears in important quantities at the beginning of the Cretaceous system. They concluded, that clay mineral assemblages can be used as stratigraphical key horizons. PERSOZ (1982) correlates clay mineral horizons from the Lake of Constance to the Grenoble region, using the clay mineral assemblages as mineralostratrigraphical markers. This same author confirms that the inherited character dominates largely the diagenetic transformations of the clay fraction. On the contrary, DARSAC (1983) shows up relations between the nature of the sediments and its clay mineral associations, thus questioning whether one should rely on the mineralostratigraphical key horizons proposed by PERSOZ. BAUSCH (1980), DECONINCK (1984, 1987), DECONINCK et al. (1985) and DECONINCK & DEBRABANT (1985) explain the clay mineral associations mainly by climatic, eustatic and tectonic influences.

Concerning the Jurassic - Cretaceous boundary, the proposals made at the Colloque Lyon/Neuchâtel (1973) have been applied. The majority of the participants to this congress had agreed to lower the Jurassic - Cretaceous boundary to the lower limit of the *Jacobi*-Zone, which is almost identical with the *Calpionella*-Standard Zone (tab. 3). Nevertheless, this proposal was not accepted by everyone and even in recent publications there is some confusion concerning the Jurassic - Cretaceous boundary.

1.4. Working Methods

About 10 g of each sample were first crushed, then decalcified in a solution of 200 ml hydrochloric acid (10%) and shaken in a glass vessel with compressed air during some 25 min. This timing usually turned out to be sufficient, but the exact duration of the decalcification process depended on the carbonate content. The decalcification vessel was also treated with ultrasonics in order to obtain a better separation of the insoluble residues from the carbonates. After this, the samples were washed out by centrifugation with water of pH 7.5. The two fractions <2µm and 2-16 µm were separated according to a method developped and improved by KÜBLER (1983) and RUMLEY & ADATTE (1983). This procedure allowed the preparation of oriented aggregates on glass slides.

The air-dried oriented aggregates ("Texturpräparate" JASMUND 1955) were analysed by X-ray diffraction (XRD). These analysis were performed in the Mineralogical and Geochemical Laboratory of the Geological Institute of the University of Neuchâtel. We used a PHILLIPS diffractometer (40 kV, 20 mA, Cu K α radiation, Ni filter, slit1°, speed 2°2θ/min, without monochromator (KÜBLER 1986, 1987). The oriented pastes were satured with ethylene-glycol during at least twelve hours, after which a second XRD was carried out.

The method we used for our analysis can be considered as quite reliable: diffraction patterns from different samples of the same emplacement, but prepared by different investigators, where found to be practically identical.

For the interpretation the absolute intensity was mesured in mm (corresponding to cps) over the background on normal and glycolated diffraction patterns (2° - 50°): after that the relative percentages of the insoluble residue (="clay residue") were calculated. The curves of relative percentages show the evolution of the mineralogical assemblages. In comparison with the litholog of the profile, possible correlations between the mineralogical associations and the lithology can be shown.

The illite crystallinity index, which corresponds to the width of the illite 001 peak at half height (KÜBLER 1967a, 1984b), is measured in °2θCuKα on air-dried diffraction patterns. Therewith we apply the original definition for the illite crystallinity index given by KÜBLER.

The biochronological control is essentially given by Calpionellids. Thin sections were made for a portion of the samples. This will reveal possible horizontal correlations between biostratigrafically dated layers and their clay mineral assemblages.

2. Mineralogy

2.1. Introduction

In the present paper we deal with results obtained from interpretation of XRD of the following minerals:

- corrensite
- smectite
- unspecified mixed-layer minerals
- kaolinite
- chlorite

We did separate kaolinite and chlorite with a formula proposed by BISCAYE (1964), because the 001peak of kaolinite and the 002 reflection of chlorite are coincident.

$$\text{factor chl} = \frac{\text{int chl 004}}{\text{int chl 004} + \text{int kao 002}}$$

$$\text{factor kao} = \frac{\text{int kao 002}}{\text{int chl 004} + \text{int kao 002}}$$

such that factor chl + factor kao = 1

These "factors" are multiplied with the intensity of the combined peaks of kaolinite and chlorite at 7.1 Å and, as a result, we obtain the corrected intensity for the two minerals.

Here is an example:

int(kao 001+chl 002) = 50, int kao 002 = 25, int chl 004 = 10

$$\text{factor chl} = \frac{10}{10 + 25} = 0.28 \quad \text{int chl cor. } 0.28 \times 50 = 14$$

$$\text{factor kao} = 1 - 0.28 = 0.72 \quad \text{int kao cor. } 0.72 \times 50 = 36$$

Concerning our analysis, we did not use the intensity-correction factors proposed by BRADLEY (1953), JOHNS, GRIM & BRADLEY (1954) or MANN & MÜLLER (1980) because we do consider our results only as semiquantitative and therefore it sems to make no sense to enlarge the possibilities of error of our measurements. The relative percentages have been calculated directly from the intensities mesured in mm that correspond, multiplied by a factor, to cps on the diffraction patterns.

2.2. Mineral Identification and Stratigraphical Range

2.2.1. Corrensite

Corrensite is a regular mixed-layer clay mineral of the AB type which consists of a regular alternance of swelling (smectite) and non-swelling layers (chlorite). In our samples corrensite has been identified through its strong 001 peak on normal diffaction patterns. This peak is displaced towards 32 Å on glycolated diffraction patterns. Furthermore, we could also identify the peaks up to 0010 except 005 and 007. This justifies our interpretation of these peaks as corrensite. Very often, a background of chlorite accompanies corrensite. According to KÜBLER (1973) the occurence of corrensite is associated with three different facies:

- clays of evaporites, sulfates and salt,
- limestones, dolomitic limestones, dolomites,
- pyroclastics, volcanic-detritic rocks, basic effusive rocks, or grauwackes.

In our case we can certainly eliminate the first and the third possibilities. Concerning the association of corrensite with carbonate facies it has to be said that the existence of dolomite in corrensite bearing horizons could not be prooved in our analysis. Corrensite was found in micritic limestone horizons, which showed no difference from roof or floor rocks. On the other hand, the presence of corrensite is too irregular for use as stratigraphical or paleogeographical marker. According to FREY (1987), the occurence of corrensite can also be explained as an intermediate stage of transformation from smectite into chlorite.

We could identify corrensite only in some profiles:

- Ardèche region (Ang, RdG),
- in the central part of the Basin (Mia, SJu),
- in the southeastern edge of the Vercors (Cpl).

In the Ardèche, as well as in the center of the Basin, a correlation of a corrensite-bearing horizon with the Lower / Upper Tithonian boundary seems possible (*Chitinoidella*-zone resp. *Crassicollaria*-zone, c.f. fig.2). Otherwise, corrensite occurs in the uppermost Tithonian (Cpl) and at the very beginning of the Berriasian (Mia, SJu). However, its presence is too irregular to be of use for regional mineralostratigraphical correlations.

2.2.2. Smectite

In this study preference is given to the term "smectite" instead of "Montmorillonite" . We use this designation to characterize a phyllosilicate that is identified through its 001 peak at 14 Å (BRINDLEY & BROWN 1980). After saturation with ethylene-glycol a deplacement of this peak towards 15 or 17 Å is observed. This corresponds to the swelling of the interfoliated layer. The 002 and the 003 reflections did not appear well individualized on our diffraction patterns. It is evident, that our "smectites" may also contain a various percentage of mixed-layer clay minerals.

The following conditions of formation are known (MILLOT 1964):

- alterations of the soil (degradation of other clay minerals),
- evaporitic environments,
- volcanic influences.

In the Vocontian Basin with its open marine facies there is no evidence for an evaporitic environment. However, in the Purbeckian facies, towards the margins of the basin, such a possibility becomes very likely (TRAUTH 1977, DECONINCK & STRASSER 1987). Volcanic influences (bentonites/volcanic ashes or hydrothermal veins) can be excluded. In our case smectites are considered to be of detritic origin.

In the Vocontian Basin smectites are important components of the clay fraction. However, the distribution pattern is somewhat surprising, because in some profiles in the center of the Basin (Chr, Cht, SJu) the clay fraction contained no

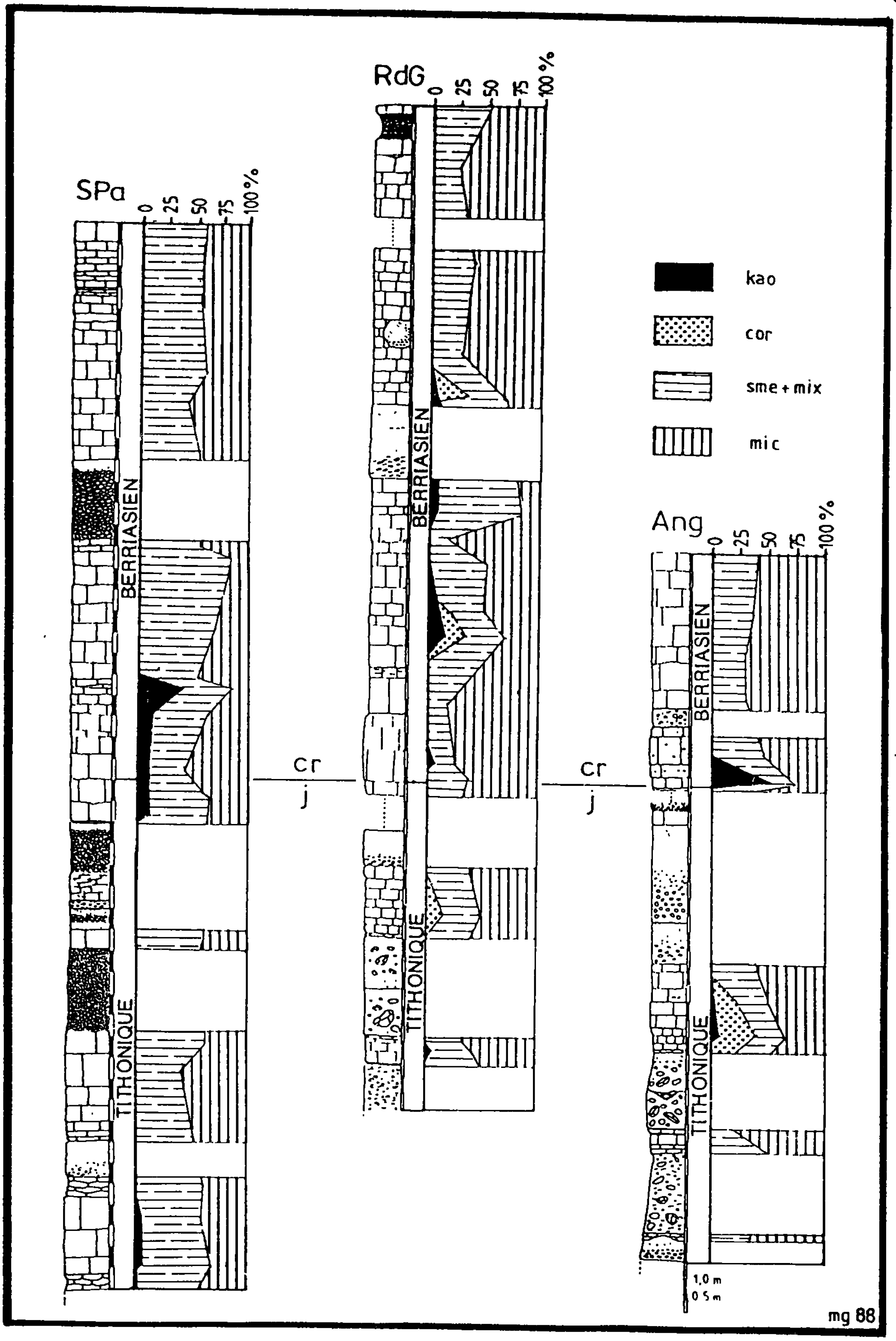

Fig. 2 Mineralostratigraphical importance of kaolinite and corrensite
Valeur minéralostratigraphique de la kaolinite et corrensite
Mineralstratigrafische Bedeutung von Kaolinit und Corrensit

smectites. Their high floatability should give the smectites a large dispersion over the Vocontian Basin. So far no explanation can be given for this puzzling result which is in opposition with investigations on recent marine sediments, as well as with PERSOZ & REMANE (1976) who claim a relative abundance of smectites in the central part of the Vocontian Basin. This observation was the more asthonishing because close to these profiles we had others (e.g. Mia, VaQ) which did contain smectite. Usually, smectites are associated with illite and mixed-layer clay minerals (c.f. 2.2.3 and 2.2.4.).

In the Ardèche (Ang, Ber, RdG) the insoluble residue contained 30 - 50% smectite.

The most important proportions (up to 70 - 80%) of smectite were reached in the following profiles: Cpl, Mia, SAu, Sia, SPa, VaQ. They are situated toward the northern, northwestern and southern margins of the basin.

At RdA, REs and Vey smectites are partly alterated into mixed-layer clay minerals (c.f. 2.2.3.). More toward the East, especially in the profiles ChO and Esp, we could observe a progressive diagenetic transformation of smectite into chlorite (c.f. 2.2.6.; "chloritization" sensu FREY 1987).

2.2.3. Mixed-layer Clay Minerals

Mixed-layer clay minerals are characterized on air-dried diffraction patterns through a serie of enlarged, flat-topped reflections (diffraction bands) between 10 - 17 Å. The highest intensity has been measured independently of its position. The great number of possible mixed-layer clay minerals causes some nomenclature confusion. KÜBLER (1961) also showed the importance of granulometry for the variety of these minerals. The exact description of the structure would consist in the determination of:

- type and proportion of components,
- irregularity or regularity of the mode of alternation.

We used the method of SRODON (1980) in VUITEL (1987) to ascertain the composition of our mixed-layer clay minerals. Corrensite is the only regular AB type we found in our samples. This mineral was discussed separately (c.f. 2.2.1.).

Mixed-layer clay minerals are formed by alternation during alteration of other clay minerals (e.g. Smectite, Illite). Being quite unstable these minerals are often transformed by diagenesis into other minerals ("aggradation" sensu DUNOYER DE SEGONZAC 1969, c.f. 2.2.6.).

Mixed-layer clay minerals are not very abundant in the Jurassic - Cretaceous boundary beds of the Vocontian Basin. Their occurence is interpretated as alteration of smectite (RdA, REs and Vey; c.f. 2.2.2.). The sections CTa and LCa showed a weak upswell between 10 and 17 Å. However, after glycolation we did not obtain a more individualized reflection. This is why we could apply the method of SRODON (1980) only to some of these mixed-layer clay minerals, those which are determined as illite - smectite with up to 10 % of swelling layers. But most of them are considered as mixed-layer clay minerals with a variable and random proportion of components of mixed-layers (KÜBLER 1961).

2.2.4. Illite and its Crystallinity

The term "illite" was originally created for a specific mineral, but is now ofted used in the literature for the whole mineral group of detritic micas. Illite is a phyllosilicate that is identified through its 001 reflection at 9.92 Å on air-dried diffraction patterns. Usually we found well individualized reflections. No swelling of the 001 peak is observed after glycolation. 002/001 intensity relations were first used to determine the chemical compostition of detritic micas (ESQUEVIN 1969). According to REY & KÜBLER (1983) binary and ternary intensity diagrams of the harmonic 001 series of micas in sedimentary sequences also allow to define the

Baronnies (SAu, Sia), we found only a small amount of kaolinite in some samples, without a preference for a specific stratigraphic horizon.

On the contrary, on the margins of the Basin kaolinite appears only during a short period, with a well defined maximum (fig. 3). This is the case for the Chartreuse (SPa), VaQ in the northwestern part of the Basin, the Ardèche (Ang, RdG), but also for Mia in the central part of the Basin. These profiles show quite important proportions of kaolinite (up to 30% of the insoluble residue), but only in the first horizons of the Berriasian (*Jacobi*-Zone, lower part of the *Calpionella*-Standard-Zone). With certain restrictions we agree with PERSOZ & REMANE (1976) and PERSOZ (1982) when these two authors propose to use kaolinite as a mineralostratigraphical marker. However, we do not overestimate the result of our observations and attach only a local importance to this phenomenon, and we also avoid to make isochronous correlations between these profiles.

2.2.6. Chlorite

Chlorite has been identified through its 002 and 004 reflections. The intensity was mesured and corrected after BISCAYE 1964 (c.f. 2.1.). The 001 reflection at 14.1 Å and the 003 peak at 4.72 Å are usually too weak and could not be measured. As shown in HOLTZAPFFEL (1985), the 002 and 004 reflections are always more important in Fe-rich chlorites.

Different modes of formation are known for chlorite:

- climatic conditions,
- diagenetic transformations of existing clay minerals,
- neoformation in evaporitic or salt facies,
- influences of thermal metamorphism.

From investigations in recent ocean sediments (BISCAYE 1965) we know that chlorite usually indicates a cold (arctic) climate. This fact explains the general absence of chlorite in the Vocontian Basin during the interval studied.

On the other hand, the existence of chlorite in the Eastern part of the Subalpine Chains indicates diagenetic transformations through burial of mixed-layer minerals and/or transformation of smectites into chlorites (DECONINCK & DEBRABANT (1985) for the Upper Jurassic and DUNOYER (1969) for the "Terres noires" of the Oxfordian).

Finally, it should be mentioned that part of the chlorites might have been destroyed during the acid treatment of the decalcification process (BROWN 1961; c.f.1.4.).

In the center of the Vocontian Basin, in its Northern borderlands as well as in the Cevennes region, no chlorite has been found in our analysis. Only a small proportion of chlorite was found in some samples of the Lower Berriasian in Ardèche (RdG: max. 7% of insoluble residue). The two profiles situated in the Baronnies (SAu, Sia) contain up to 8% chlorite in the insoluble residue - without any preference for a stratigraphic horizon. Toward the eastern part of the region studied, in direction of the Alps, a progressive (ChO, Esp, REs) resp. total transformation (Dal, JuV, Ver, Vey) of mixed-layer minerals and/or smectites into chlorite was observed ("aggradation" sensu DUNOYER DE SEGONZAC 1969, "chloritization" sensu FREY 1987; c.f. 2.2.3.). In this region the clay fraction consists only of illite and chlorite. These two minerals are considered to be the typical components of the insoluble residue in the anchizone (c.f. 2.2.4.). These sections are also those which are situated in the nappe of Digne, where thermal diagenetic transformations of existing mineral assemblages caused by the alpine orogeny are more likely than in the center of the Vocontian Basin. Future studies will deal with this interesting observation which was also made by FERRY, COTILLON & RIO (1983) for alternances of isochronous levels of Valanginian marls and limestones in the same region, as well as by DECONINCK & CHAMLEY (1983) in a more general approach.

determination of their chemical composition. It turned out that the chemical composition of our mica corresponds mostly to illite resp. illite-phengite all over the studied region and throughout the whole interval under consideration (c.f. fig.3).

The various modes of formation of Illite are described by MILLOT (1964).

Measurements of the crystallinity of illite ("sharpness ratio": WEAVER 1960, "indice d'aigu": KÜBLER 1964, "largeur de Scherrer" KÜBLER 1984b) allow a quantitative evaluation of beginning metamorphism. According to KÜBLER (1964, 1967a etc) the illite crystallinity index corresponds to the width of the 001 reflection at half peak height and is mesured on air-dried diffraction patterns. This index, from now on called "KI" (= "KÜBLER index"), allows a zonation of diagenesis and lower stages of metamorphism (KÜBLER 1984b). However, these values depend on adopted experimental conditions. Therefore, illite crystallinity standards must be used and experimental conditions should be mentioned (KÜBLER 1984a, 1984b). Therefore, results from other laboratories, even if obtained with the same diffractometer, can in general not be compared (c.f. 1.4.).

In application of KÜBLER 1984b the limiting values for the low-grade and high-grade limit of the anchizone are 0.42 and 0.25 $\Delta°2\theta CuK\alpha$. Our mesurements showed a distribution pattern indicating in most of the samples a good crystallinity (anchizone). In one profile (SJu) we did not mesure KI because the intensity of the 001 peak of illite was too weak. Generally the values of crystallinity were found to decrease from West to East. The same observation has been made for instance by SIDDANS (1977) for the Terres Noires Formation of the Oxfordian.

With 40 to 60 % illite was omnipresent in all profiles of the Vocontian Basin over the studied interval and it usually is the main component of the insoluble residue (c.f. 2.2.2). In the internal part of the subalpine region (nappe of Digne: Dal, JuV, Ver) we found the characteristic association of the anchizone: the clay fraction consists only of illite and chlorite (c.f. 2.2.6.), with illite proportions varying between 60 and 70 %. We consider this illite partly as authigenous (illitisation of kaolinite; c.f. 2.2.4.). The same conclusion was obtained by DECONINCK & STRASSER (1987) for illite in the Purbeckian facies (illitization of smectite: FREY 1987; c.f. 2.2.2.).

2.2.5. Kaolinite

The mineral is identified through its 001 and 002 reflections. In samples containing chlorite the distinction between the two minerals was made according to the method of BISCAYE (1964; c.f. 2.1.).

Kaolinite can be of pedogenic or hydrothermal origin and a neoformation of kaolinite due to the circulation of acid solutions is also known (MILLOT 1964, DUNOYER DE SEGONZAC 1969).

The alteration of soil in a humid and warm climate ("kaolinitisation") is certainly the most important factor for the neoformation of kaolinite and its transport into continental or marine basins. Kaolinite in the studied area is considered to be of detritic origin. Hydrothermal influences as well as diagenetic transformations, can be excluded for the Vocontian Basin.

Whatever the exact conditions for transformation and dissappearance of kaolinite may be, we are able to show that its distribution in the Vocontian Basin is limited to the central part, the Northern and Western borderlands. On the contrary, there is no evidence for kaolinite in the profiles situated in the internal part of the region studied (nappe of Digne). This phenomenon is explained as a diagenetic degradation of kaolinite into illite ("illitization" sensu FREY 1987, c.f. 2.2.4.). The same distribution pattern of kaolinite was found in the Valanginian limestone - marl alternances of the Vocontian Basin (FERRY, COTILLON & RIO 1983).

In greater detail, the distribution of kaolinite is as follows:

In the center of the Basin (Chc, Chr, Cht, SJu) kaolinite is an essential element of the insoluble residue (30 - 40%) for the entire interval. Toward the North the proportions are reduced to 10 - 15% (Cpl), and toward the South, in the

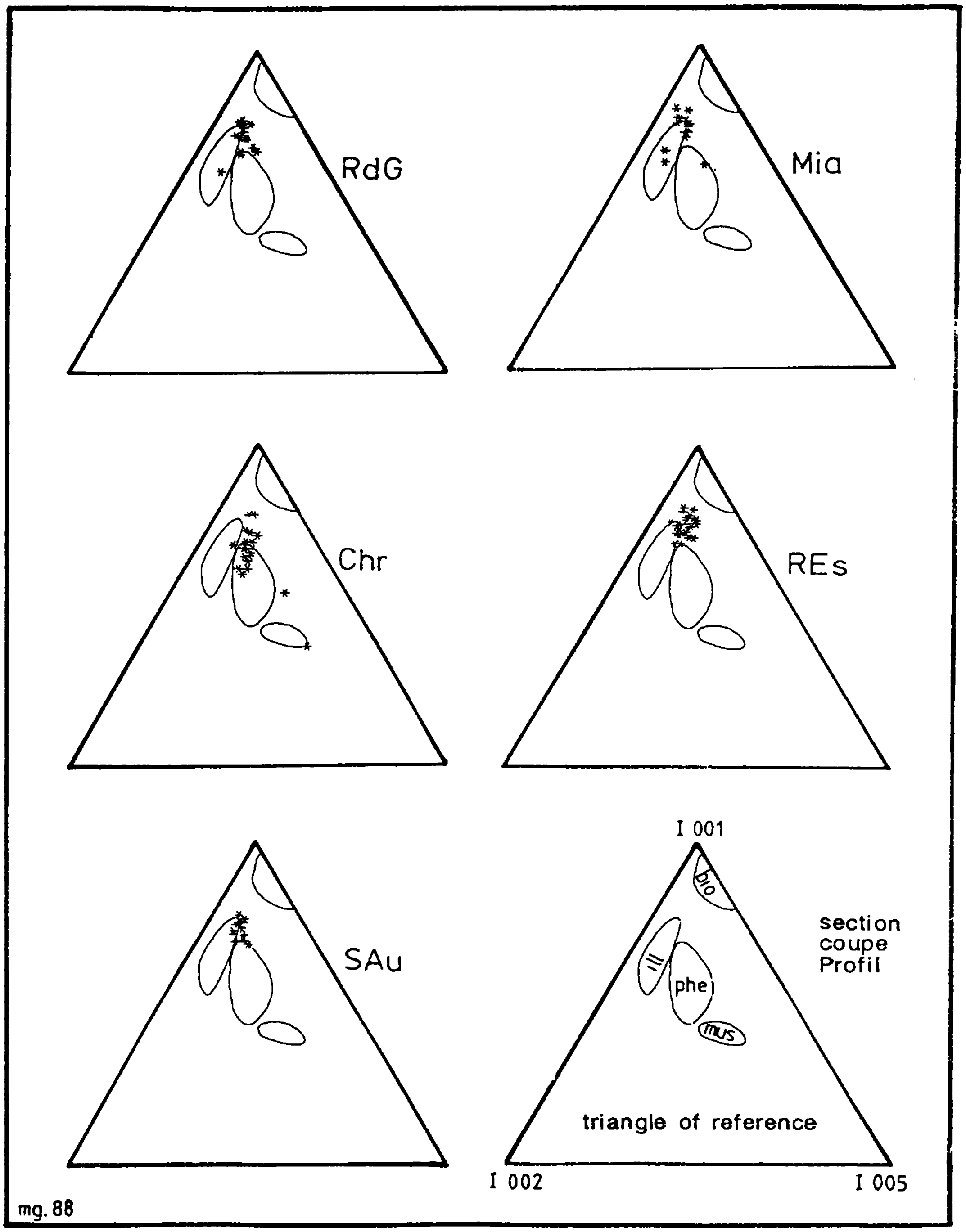

Fig. 3 Chemical composition of the mica [<2 μm]
Compostion chimique des micas [<2 μm]
Chemische Zusammensetzung der Glimmer [<2 μm]

3. Conclusions

The biochronological calibration of our samples allows the comparison of the clay fraction of isochronous layers throughout the studied area. As a result of our investigations it turns out that there is usually little change in the mineralogical composition of the clay fraction within the same section. Illite is omnipresent allover the region studied. The presence of corrensite is too irregular to be of use for mineralostratigraphical correlations. Regional differences in the distribution of the clay minerals are more important. Two cross-sections (fig. 4 and 5) show the horizontal evolution and changes in the composition of the insoluble residue. The presentation is based on average relative % values of each mineral during the studied interval (Tithonian - Berriasian).

The distribution pattern of fig. 4 and 5 can be summerized as follows:

- the distribution pattern of smectite is somewhat surprising, because this mineral was usually absent in the center of the Basin. The most important proportions of smectites were reached towards the northern and the southern margins of the Vocontian Basin.

- mixed layer clay minerals are not very abundant in the Jurassic-Cretaceous boundary beds of the Vocontian Basin. Their occurence is limited to its western margin.

The separation of these first two minerals was not always possible on our diffraction patterns. Therefore it seemed preferable to unite their calculated percentages in fig. 4 and 5.

- illite is omnipresent in all profiles over the whole studied interval. Measurements of the crystallinity according to KÜBLER 1984b showed a tendency towards a better crystallinity in the eastern part of the studied region, that is also characterized by increasing amounts of mica in the insoluble residue. The chemical composition of the mica has been determined as illite resp. illite-phengite.

- in the center of the Vocontian Basin kaolinite is an essential element of the insoluble residue for the entire interval. Kaolinite proportions diminish towards the North and the South. With some restrictions, kaolinite can be used as a mineralostratigraphical marker for the beginning of the Cretaceous at the Northern and Western border of the Vocontian Basin.

- No chlorite has been found in the center of the Basin. Small chlorite proportions appear in different stratigraphic horizons of the Ardèche and Baronnies regions. Towards the Alps, diagenetic influences are responsable for a progressive resp. total transformation of mixed-layer clay minerals and/or smectites into chlorite.

For the studied region and the interval under consideration we are not able to show distinct "clay mineral provinces" as it had been stressed out by BAUSCH (1980). According to this author changes in clay mineral assemblages are essentially due to climatic and eustatic influences. On the contrary, we explain changes in the composition of the insoluble residue as effects of diagenetic transformations. It should also be mentioned that BAUSCH used a different method of illustration: he did not show the evolution of the composition of the insoluble residue as we did in fig. 3, 4 or 5 but by means of relations between quotients of clay mineral proportions. For this reason the results are not perfectly comparable. We also cannot apply the results of GYGI & PERSOZ (1986), obtained for the Oxfordian of the Jura platform, where these authors suggest kaolinite being a good and reliable mineralostratigraphical marker. And we could furthermore not observe a prolongation of the Upper Jurassic kaolinite key-levels of the Jura plateform (PERSOZ 1982) into the Vocontian Basin.

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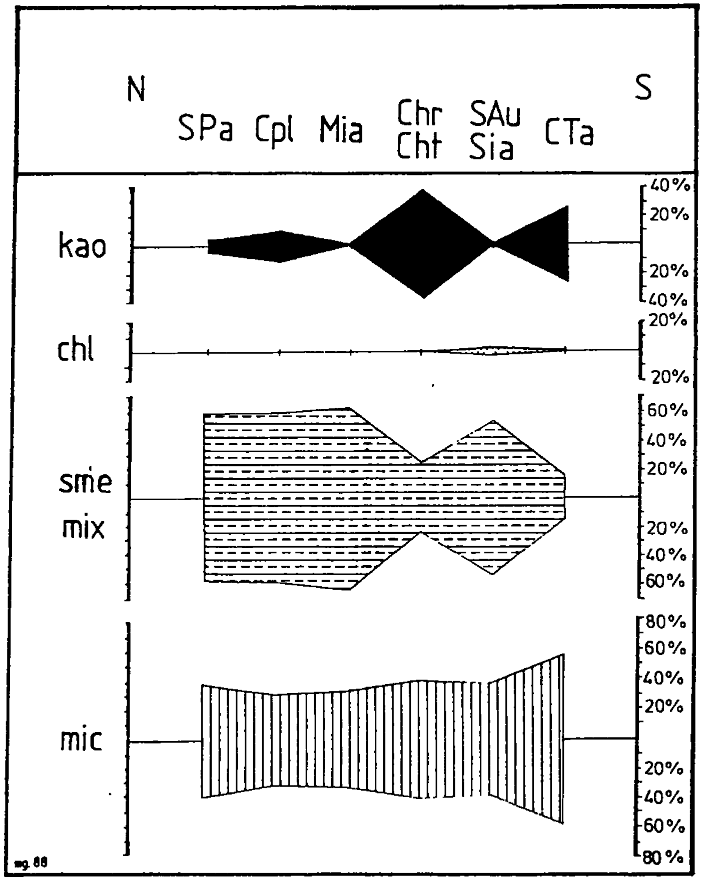

Fig.4

Distribution of Clay Minerals on a N-S oriented Cross-section [fraction <2µm]

Distribution des minéraux argileux sur une profile orientée N-S [fraction <2µm]

Verteilungskurve der Tonmineralien entlang eines N-S orientierten Profiles [Fraktion <2µm]

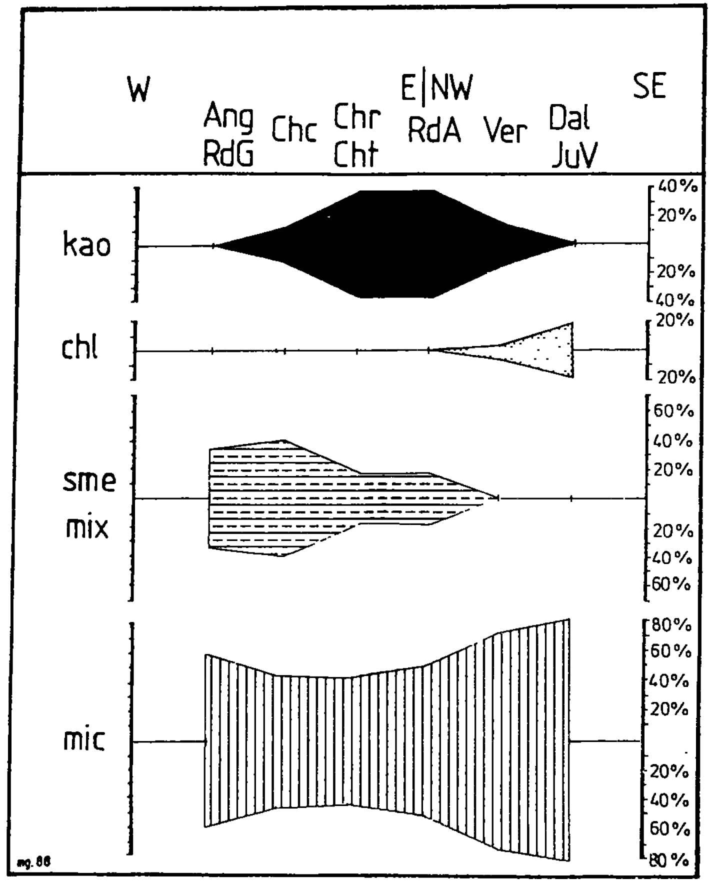

Fig.5

Distribution of Clay Minerals on a W-E/NW-SE oriented Cross-section [fraction <2µm]

Distribution des minéraux argileux sur une profile orientée W-E/NW-SE [fraction <2µm]

Verteilungskurve der Tonmineralien entlang eines W-E/NW-SE orientierten Profiles [Fraktion <2µm]

to my disposal. R. JANTSCHIK (Neuchâtel) introduced me into the world of ternary intensity diagrams. I also wish to thank G. FISCHER (Neuchâtel) for his review of the manuscript.

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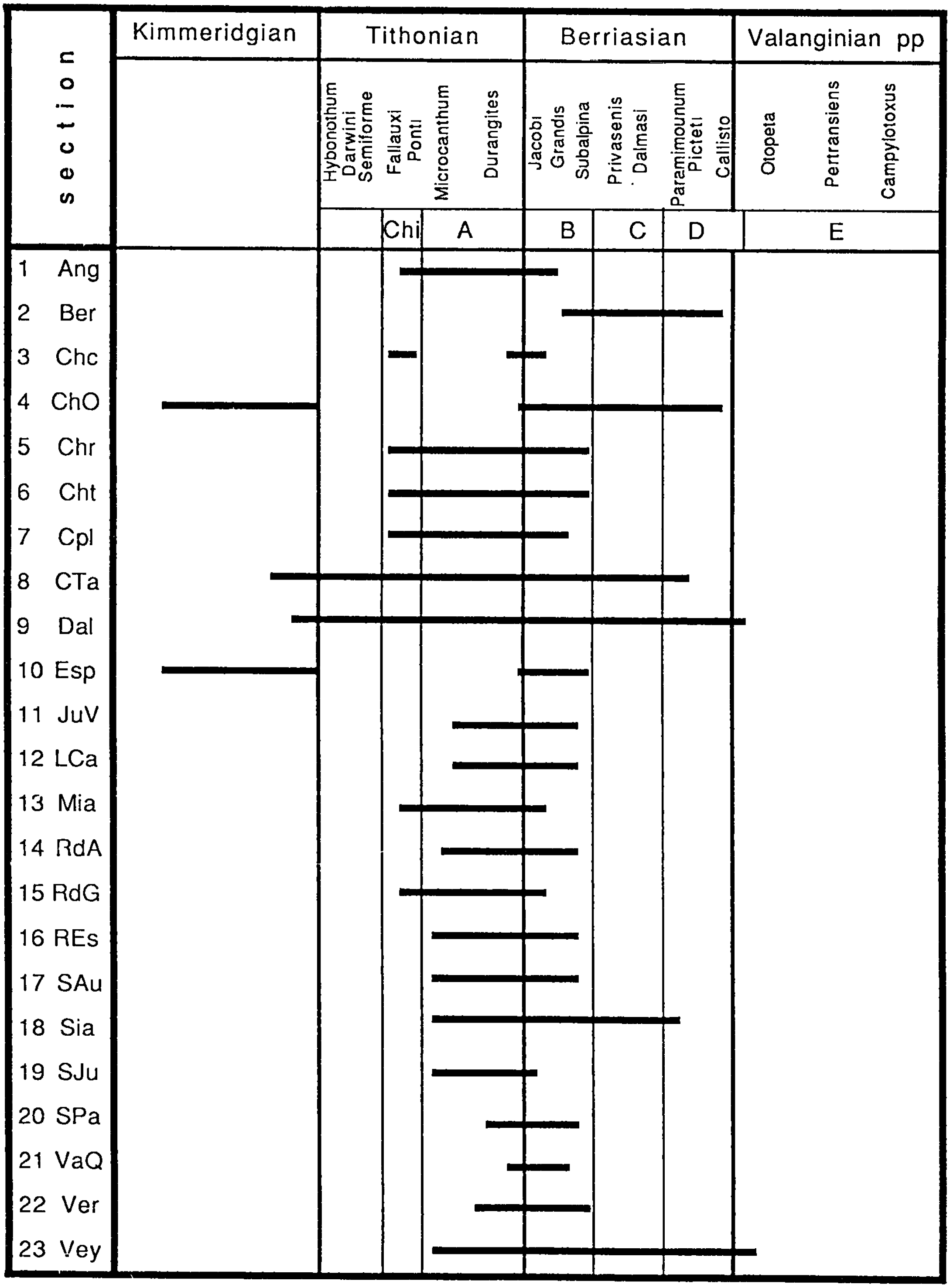
	name of the section		sample	geological map
1	Carrière des Anges	Ang	15	Privas (198) 1:80.000
2	Berrias	Ber	75	Alès (209) 1:80.000
3	Chalancon	Chc	20	Dieulefit (867) 1:50.000
4	Chateâuneuf-d'Oze	ChO	55	Gap (869) 1:50.000
5	Charens	Chr	24	Luc-en-Diois (868) 1:50.000
6	Le Chouet	Cht	33	Luc-en-Diois (868) 1:50.000
7	Chauplane	Cpl	33	La Chapelle-en-Vercors (820) 1:50.000
8	Clue de Taulanne	CTa	52	Moustiers-Ste.Marie (970) 1:50.000
9	Daluis	Dal	50	Entrevaux (945) 1:50.000
10	Espréaux	Esp	30	Gap (869) 1:50.000
11	Saint Julien-Vergons	JuV	29	Castellane (971) 1:50.000
12	La Cadière	LCa	25	Le Vigan (221) 1:80.000
13	Les Miaux	Mia	15	Luc-en-Diois (868) 1:50.000
14	Roche des Arnauds	RdA	36	Gap (869) 1:50.000
15	Route des Grads	RdG	20	Privas (198) 1:80.000
16	Roc de l'Esculier	REs	32	Le Buis (211) 1:80.000
17	Au Sud d'Aulan	SAu	22	Sederon (916) 1:50.000
18	Les Sias	Sia	35	Vaison-la-Romaine (915) 1:50.000
19	Saint Julien	SJu	33	Luc-en-Diois (868) 1:50.000
20	Saint Pancrasse	SPa	19	Domène (773) 1:50.000
21	Vachères-en-Quint	VaQ	10	Die (843) 1:50.000
22	Le Vernet	Ver	45	Digne (212) 1:80.000
23	Veynes	Vey	40	Gap (869) 1:50.000

Tab.1

List of the sampled sections

Liste des coupes étudiées

Verzeichnis der untersuchten Profile



Tab.2 Stratigraphical range of the studied sections
Repartition stratigraphique des coupes étudiées
Stratigraphische Reichweite der untersuchten Profile

			Ammonites	Calpionellids			
Cretaceous	Valanginian	Early	Campylotoxus	?			?
			Pertransiens	E			Calpionellites
			Otopeta				
	Berriasian	Boissieri	Callisto	D	3	Oblonga	Calpionellopsis
			Picteti		2		
			Paramimounum		1	Simplex	
		Occitana	Dalmasi	C			Calpionella
			Privasensis				
			Subalpina	B			
		Euxinus	Grandis				
			Jacobi				
Jurassic	Tithonian	Late	Durangites	A	3	Intermedia	Crassicollaria
					2		
			Microcanthum		1	Remanei	
		Early	Ponti				Chitinoidella
			Fallauxi	?			?
		↓	Semiforme				

Tab.3

Biochronological zonation for the Jurassic - Cretaceous boundary beds in SE France

Zonation biochronologique du passage Jurassique - Crétacé du SE de la France

Biochronologische Untergliederung für die Jura - Kreide Grenzschichten in SE Frankreich

after/selon/nach REMANE et al.(1986)